Organization and Conway's GOL

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Last Week

Last week we talked about life emerging to dissipate energy gradients. This ansatz was an attempt to explain how complexity and organization, which necessarily involve states of non-maximal entropy, can exist in spite of the 2nd law of thermodynamics, i.e. that closed systems tend to a state of maximal entropy. As we saw, open systems within a larger closed system can increase the entropy of the enclosing system by dissipating energy and decreasing their entropy.

Biological life not the only case where organization arises out of energy/temperature gradients. The two examples we brought up last week were convection cells and turbulence. We might wonder, then, *how simple of a model do you need to see organization arise?* In particular, I wanted to investigate whether this phenomenon could be observed in simple cellular automata such as Conway's Game of Life.

The Game of Life

Previously, people have scrutinized the Game of Life and found various interesting behavior, cool, alien-like "reproducing" forms. However, the interesting behavior came out of extremely constructed environments. Furthermore, the standard game of life is deterministic. How can we speak of order or disorder in such a case? How can we talked about "emergence," when there's nothing out of which to emerge? One way to speak of order or organization is in terms of correlations. On a small scale, though, the rules of the Game of Life guarantee correlation. Recall the typical GOL algorithm:

```
X = (X & (N == 2)) |    (N == 3) )
```

where X is the boolean value of the site, N is the number of neighbors of value 1, and the symbols & and | represent the logical operators "and" and "or", respectively.

One possible path of investigation would be to use random initial configurations like Garcia, et al.
What I did instead was introduce a “temperature” like Schulman & Seiden. The algorithm rule then becomes:

```
X = ( ( (Temprand < (1 + numden*temp)/(1 + temp)) & ( (X & (N == 2))    |
(N== 3) )) + ( (Temprand < (numden*temp)/(1 + temp)) & ( (~X & (N ~=
2) ) | (N ~=3)) )  );
```

where *Temprand* is a randomly generated number between 0 and 1, *numden* is the total number of cells with value 1, and *temp* is the “temperature” parameter which controls the rate of stochastic variation. The temperature term tends to de-correlate neighboring sites. We wonder, then, will “life” persist? That is, can big structures still result?

Under the modified rule, there is no visually obvious organization that persists over multiple iterations/time-steps, although I was able to reproduce the phase transition found by Schulman & Seiden.

I attempted further modifications. In particular, I wanted to create some sort of gradient to dissipate. I did this in two ways. One strategy was to have fixed sources of “life”, that is cells that were permanently turned on. I also experimented with creating a “temperature gradient,” so that stochastic fluctuations were more probable at one end of the box than the other.

The results were nothing mind-blowing. It is possible to see recurring patterns, reminiscent of vortices. This is encouraging. To solidify these observations it would be necessary to investigate density correlations across different size scales. However, given the time and scope of this presentation, I didn’t have time to implement correlation calculations.

Lattice Gas Model

Maybe, then, cellular automata are too simple to investigate this organization-through-dissipation behavior. As it would happen, however, there is a family of cellular automata referred to as the Lattice Gas Model which has been used to simulate complex fluids. Though clearly an imperfect, it is possible to generate turbulent fluid behavior.